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Wind energy status in renewable electrical energy production in Turkey

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ABSTRACT

Main electrical energy sources of Turkey are thermal and hydraulic. Most of the thermal sources are derived from natural gas. Turkey imports natural gas; therefore, decreasing usage of natural gas is very important for both economical and environmental aspects. Because of disadvantages of fossil fuels, renewable energy sources are getting importance for sustainable energy development and environmental protection. Among the renewable sources, Turkey has very high wind energy potential. The estimated wind power capacity of Turkey is about 83,000 MW while only 10,000 MW of it seems to be economically feasible to use. Start 2009, the total installed wind power capacity of Turkey was only 4.3% of its total economical wind power potential (433 MW). However, the strong development of wind energy in Turkey is expected to continue in the coming years. In this study, Turkey's installed electric power capacity, electric energy production is investigated and also Turkey current wind energy status is examined.

Contents

1. Introduction . . . 2104
2. Wind energy for renewable electricity . . . 2105
3. Wind power and the environment . . . 2106
   3.1. Environmental benefits. . . . 2106
   3.2. Environmental impacts. . . . 2106
4. Global wind energy . . . 2107
5. Turkey's electrical energy status . . . 2109
6. Wind energy in Turkey . . . 2109
7. Wind energy supports and prices . . . 2110
8. Conclusions . . . 2111
   References . . . 2112

1. Introduction

There has been a significant increase in electrical energy demand due to the economical and technological developments over the world. The global economy grew 3.3% per year over the past 30 years. In this period the electrical energy demand increased 3.6% [1]. The electrical energy production of the world in 2007 was 16,429 TWh [2] and it is estimated that the world will consume 28,930 TWh in 2030 [2]. In order to supply the required electricity demand, thousands of new power plants had to be built.

Electrical energy production has been mainly derived from limited sources. Because of this fossil sources will be consumed in the future, studies on electrical energy production with renewable sources such as hydraulic, solar, wind, biomass and geothermal continue on with the energy saving studies at the same time. It is now widely accepted that renewable energy sources are very important for the future of the countries. The ratio of the electric power produced via usage of renewable resources except hydroelectricity in 2007 is only 3% and it will be intented to increase this proportion up to 6% until 2030 [2]. It is expected that biomass and wind energy will have a great effect in this increase. The objective is to increase the wind energy up to 920 TWh with a rate of 3% of the world electricity production in 2030 [1], which has a 2.0% proportion in 2007 [2]. So the greatest increase will be in wind energy production. This rate reached 20% in Germany, 6% in Denmark for the year 2007 [3–5].

Wind energy is domestic, independent to abroad, natural and infinite, obtained in the future as same amount, does not

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cause acid rain or atmospheric heating, no CO_2 emission, no harm to nature and human health, providing fossil fuel saving, no radioactive effect, fast technological development and currency gaining sources [6–8]. Turkey has very high wind potential and should benefit from this source, which has many advantages [9–17].

In this paper, Turkey's existing electrical energy status is investigated and according to the recent developments on wind energy in the world, Turkey's wind energy status is considered and things to be done on this issue are stated.

2. Wind energy for renewable electricity

Choice of design parameters is critical for optimizing wind turbine (WT) performance. For any fixed diameter there are various parameters influencing energy production: rotor rotation velocity, blade number, aerofoil chord distribution, and longitudinal blade twist. These parameters must be optimized by taking into account the turbine site and local wind intensity so the whole range of wind velocities and their direction. This distribution is well known in the literature as being represented by a Weibull distribution with its relative shape and scale parameters [18].

The objective is to maximize for a given WT site its annual energy production (AEP). By analyzing the performance parameters of a WT, the AEP grows directly with the most part of them, whereas for other parameters the analysis is much more complex. For example, as rotational velocity increases, higher power curve values increase at the cost of higher cut-in values. On the other hand, as the blade number increases, the power coefficient even more approaches the theoretical Betz limit [19]. Even for the aerofoil chord, it shows an energy production increasing with small positive variations of it. For WTs equipped with adjustable angles of attack, it is well known in the literature [19] that they can be adjusted accordingly for power.

The choice of twist variation along the blade throughout its range is a much more complex task. The literature often quotes the optimum WT design as having an angle of attack equal to the angle which maximizes the ratio between lift and drag coefficients at the on-design velocity. In reality WTs always work in off-design conditions, so it is not possible to obtain maximum wind energy by considering only one wind velocity rather than the whole range. It is important that wind resources will be underestimated if the average wind speed for power calculations will be used. A horizontal axis wind turbine (HAWT) can be designed to maximize AEP according to a given wind velocity distribution. Fig. 1 shows the probability density function taken into account for the WT design [18].

Velocity distribution shows an annual availability of 86% and it can be represented by a Weibull distribution (Eq. (1)) having an average velocity of $v = 4.6$ m/s, shape parameter $k = 1.7559$, and scale parameter $c' = 5.5082$ [18] as follows:

$$F_{\text{Weibull}} = \frac{k}{c} \times \left(\frac{v}{c}\right)^{k^{-1}} \times \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (1)$$

Fig. 2 shows the wind rose for the proceeding distribution. On the other hand, the various grey tones refer to velocity intervals reported in the tables attached to Fig. 2, the prominent wind direction being N-NE, whereas the percentages refer to the different velocity intervals along that direction.

The 'bin' method was used to evaluate AEP. AEP is based on the knowledge of the histogram (Fig. 1) which characterizes the wind resource of a wind site, and on the power curve, P_w, of the designed WT.

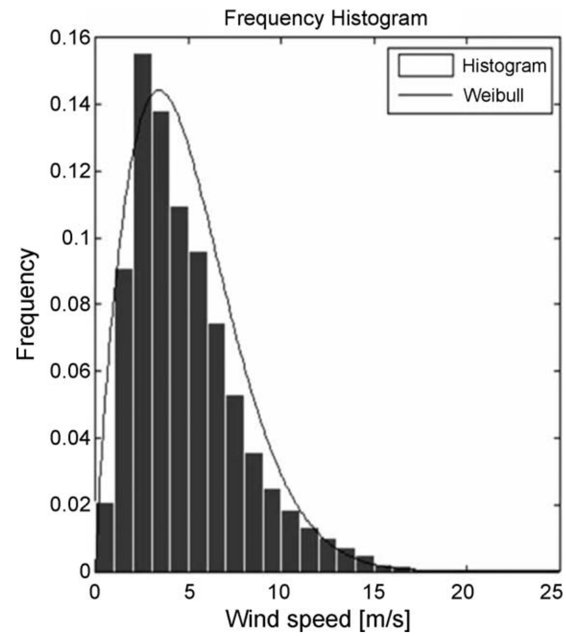


Fig. 1. Frequency histogram and wind speed frequency Weibull representation [18].

As reported in Ref. [18], the energy from a wind machine, E_w, may be evaluated as shown in Eq. (2) such as:

$$E_w = \sum_{j=1}^{N'_B} P_w(m_j)\, f_j\, \Delta t \quad (2)$$

the data are separated in N'_B bins of width w, with midpoints m_j, and with f_j, the number of occurrences in each bin or frequency. The data collected in Fig. 1 have $N'_B = 20$, $w = 1$, and $m_j = (j - 0.5)$. The data was collected over a year ($\Delta t = 8760$ h), having an annual availability of 86%, and so E_w represents the AEP.

Fig. 3 shows in the same graph, the wind speed frequency histogram, the power curve of a WT and the Betz limit for power production. To maximize AEP, the WT power curve must be as close as possible to the Betz limit curve, and/or maximize the rated power.

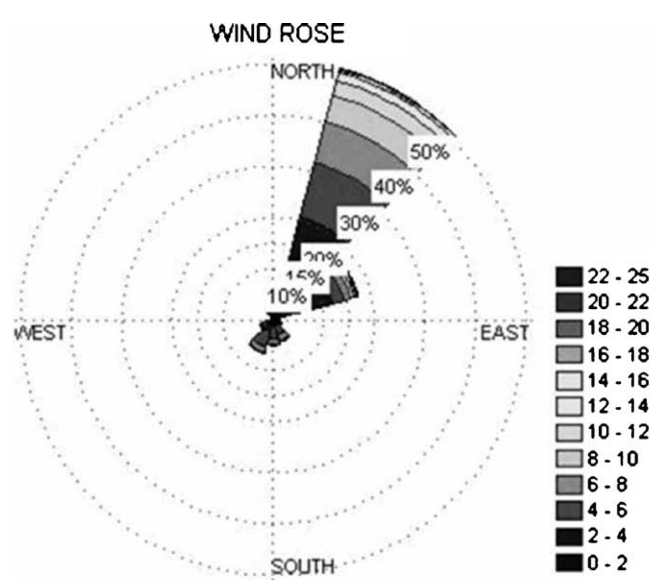


Fig. 2. Wind rose [19].

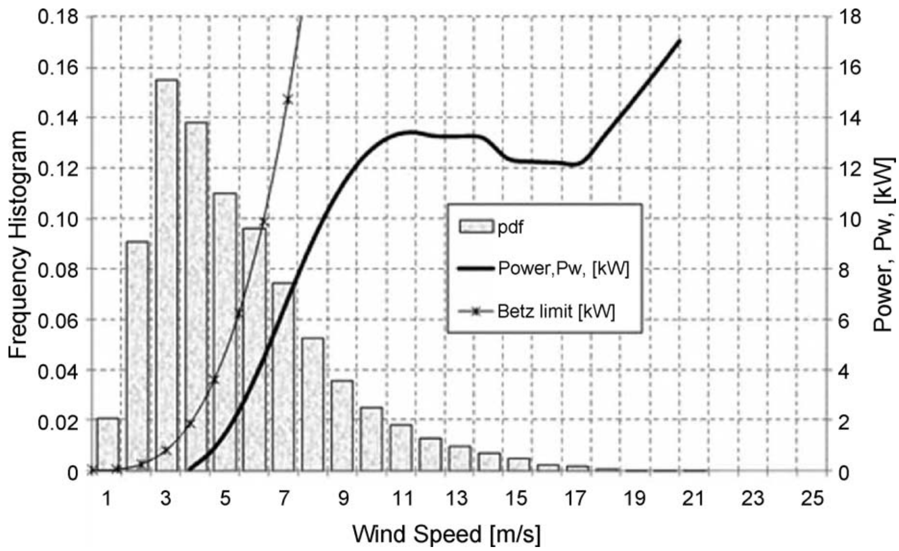


Fig. 3. Histogram, power curve of a WT, and the Betz limit [18].

3. Wind power and the environment

3.1. Environmental benefits

Wind power is a clean, emission-free power generation technology. Like all renewable sources it is based on capturing the energy from natural forces and has none of the polluting effects associated with 'conventional' fuels. On the other hand, first and foremost, wind energy produces no carbon dioxide—the main greenhouse gas contributing to climate change during its operation, and minimal quantities during the manufacture of its equipment and construction of wind farms. By contrast, fossil fuels such as coal, gas and oil are major emitters of carbon dioxide [20–22].

The International Panel on Climate Change's (IPCC) 4th Assessment Report [23] leaves no doubt that climate change is both man-made and already happening. It also warned that in order to avert the worst consequences, global emissions must peak and start to decline before 2020. The potential of wind energy to curb global emissions within this timeframe is therefore key for the long-term sustainability of the power sector [1]. The power sector today accounts for about 40% of global CO_2 emissions, while any improvements in the efficiency of thermal power stations are being offset by the strong growth in global power demand. To generate the same amount of electricity as today's global installed capacity of wind power would require burning more than 25 million tons of coal or more than 17 million tons of oil every year [2]. According to the scenarios presented in this report, global wind energy capacity could reach more than 1000 GW by the end of 2020, producing about 2600 TWh of electricity per year. This would save as much as 1500 million tons of CO_2 every year [23].

Wind power also has a positive effect on the quality of the air we breathe. The combustion of fossil fuels also produces the gases sulphur dioxide and nitrogen oxide, both serious sources of pollution. These gases are the main components of the 'acid rain' effect—killing forests, polluting water courses and corroding facades of buildings; not to mention the human health effects. In China, which depends for more than 80% of its electricity on coal-fired power stations, pollution is so serious that the World Health Organization estimates that it kills upwards of 650,000 Chinese people per year [1,2,21].

Wind energy avoids the numerous issues associated with the discovery and exploitation of fossil fuels. Deaths from mining, the massive destruction of strip mining and 'hill-top removal' and fuel spills are just some of the consequences of dependence on recovering raw materials for electricity generation from under the ground. According to the Canadian government's environment department, air pollution causes an estimated 5000 premature deaths in Canada per year. Children and elderly people face the greatest risk. Nearly 12% of Canada's smog is the result of burning fossil fuels to produce electricity [4].

The American Bird Conservancy estimates that mining operations in the states of West Virginia, Tennessee, Kentucky, and Virginia are having a massive and permanent impact on mature forest birds, including the loss of tens of thousands of breeding Cerulean Warblers [20–22]. On the other hand, shortage of supplies of natural gas in the US has resulted in a growing demand for coal-bed methane extraction of gas. This is covering the country's western prairie with drilling wells, noisy compressor stations and wastewater pits, all of which threatens wildlife habitats [3–5].

The European Union-funded research study [22] has examined in detail the economic consequences for both the environment and human health of the different ways in which electricity is produced in the EU, and found that all renewable energy sources have environmental and social benefits compared to conventional energy sources such as coal, gas, oil and nuclear. These benefits can be translated into costs for society. The EU study estimated the external cost of gas fired power generation at around 1.1–3.0 €cents/kWh and that for coal at as much as 3.5–7.7 €cents/kWh, compared to just 0.05–0.25 €cents/kWh for wind. The study concluded that the cost of producing electricity from coal or oil would double, and from gas increase by 30%, if their external costs were taken into account [3–5].

3.2. Environmental impacts

The construction and operation of wind farms, often in rural areas, raises issues of visual impact, noise and the potential effects on local ecology and wildlife. Wind turbines are highly visible elements in the landscape. They need to be tall in order to catch the prevailing wind and work effectively. In comparison to other energy developments, however, such as nuclear, coal and gas power stations or open cast coal mining, wind farms have relatively little visual impact. Nevertheless, most countries with a wind power industry have established rules which exclude certain areas from development, such as national parks or nature reserves [20]. Others have identified priority areas where wind power is specifically encouraged. On the other hand, wind farm

developers recognise that visual impact can be a concern for neighbouring communities. Considerable effort is therefore committed to the planning stages in order to reduce the impact and gain their consent. This includes the use of computer modelling programs to show residents exactly how the turbines will appear from numerous different viewpoints [3–5,20–22].

Surveys of public opinion show that most people who live near wind developments find them less intrusive once they are operating than they might have feared beforehand. Other surveys, for instance in Scotland, have shown that there is no evidence that tourism is seriously affected by the presence of wind farms. It is also worth emphasizing that wind turbines are not permanent structures. Once removed, the landscape can quickly return to its previous condition. Although a wind energy project can spread across a large total land area, it does not occupy all that space. Farming or leisure activities can still continue around the turbines. The European Wind Energy Association has estimated that the number of wind farms required to contribute 20% of Europe's electricity supply would take up only a few hundred square kilometers [3,4,21].

Compared to other types of industrial plants, wind farms are extremely quiet. Even though turbines are commonly located in rural areas, where background noise is lower, the roar of the wind often masks any sound their operation might make. Measured in a range of 35–45 decibels at a distance of 350 m from the turbines, their sound is similar to the background noise found in a typical home. On the other hand, the sounds emitted from wind turbines can either be mechanical, from internal equipment such as the gearbox or yaw drive, or aerodynamic, from air moving past the rotor blades [3,21]. Modern turbine designs have effectively reduced mechanical sound through sound proofing so that the "whooshing" aerodynamic sound is what can normally be heard. Permitted sound levels, including the distance between turbines and the nearest house, are determined at a local level. All wind farms must comply with operating rules laid down by the appropriate authorities, normally based on national recommendations [3–5].

Thousands of wind turbines have been installed around the world, many in close proximity to other types of land use, with minimal sound issues. The wind industry seeks to be a good neighbour and addresses concerns where they arise. The most significant long term threat to birds and their habitats comes from climate change. Global shifts in the climate are altering the pattern of indigenous plant species and their attendant insect life, making once attractive areas uninhabitable. According to the UK's Royal Society for the Protection of Birds, "recent scientific research indicates that, as early as the middle of this century, climate change could commit one third or more of land-based plants and animals to extinction, including some species of British birds". Compared to this threat, "the available evidence suggests that appropriately positioned wind farms do not pose a significant hazard for birds," it concludes [3,4,21].

Although birds do collide with wind turbines at some sites, modern wind power plants are collectively far less harmful to birds than numerous other hazards. The leading human-related causes of bird kills in the United States, according to the US Fish and Wildlife Service, are cats (1 billion deaths per year), buildings (up to 1 billion), hunters (100 million), vehicles (60–80 m), as well as communications towers, pesticides and power lines. Bird deaths due to wind development will never be more than a very small fraction of those caused by other commonly accepted human activities, no matter how extensively wind is used in the future [3–5,20–23].

Well publicised reports of bird deaths, especially birds of prey, at sites including the Altamont Pass near San Francisco and Tarifa in southern Spain, are not indicative of the day to day experience at the thousands of wind energy developments now operating around the world. As a general rule, birds notice that new structures have arrived in their area, learn to avoid them, especially the turning blades, and are able to continue feeding and breeding in the location. Problems are most likely to occur when the site is either on a migration route, with large flocks of birds passing through the area. Modern wind turbines, with their slower turning blades, have proved less problematic than earlier models [19–21].

Bird studies are routinely carried out at prospective wind sites in order to understand the local pattern of breeding and feeding. Pre-construction wildlife surveys by a professional consultant are common practice. These surveys help reduce the threat to birds to a minimal level. Like birds, bats are endangered by many human activities, from pesticide poisoning to collision with structures to loss of habitat. Despite publicity given to bat deaths around wind farms, mainly in the United States, studies [5] have shown that wind turbines do not pose a significant threat to bat populations. A review of available evidence by ecological consultants concluded that "bat collision mortality during the breeding season is virtually non-existent, despite the fact that relatively large numbers of bat species have been documented in close proximity to wind plants [3,4]. These data suggest that wind plants do not currently impact resident breeding populations where they have been studied."

4. Global wind energy

Total installed wind power capacity reached 120,798 MW at the end of 2008 in the world as shown in Table 1 [4,5]. Fig. 4 shows installed wind power capacity in the world between 1996 and 2007 [4,5]. There is an increasing trend in installed wind energy and average increasing rate is 30% over this period. It is estimated that installed wind power will be reached in 136,543 MW in 2010 as shown in Table 2 [4].

Approximately 62% of the installed wind capacity of the world is in the Europe, 22% in America and 16% in Asia. However,

Table 1
Breakdown of operating wind capacity (Megawatts, MW) [4].

Country/continent	End 2007	End 2008	Watts per capita
Germany	22,247	23,903	291.3
Spain	15,145	16,754	394.4
Denmark	3125	3245	589.4
Italy	2726	3736	48.3
UK	2406	3241	64
France	2454	3404	49
Portugal	2150	2862	285
Netherlands	1747	2225	110.6
Total Europe	**57,139**	**65,946**	
USA	16,824	25,170	109.4
Canada	1846	2372	70.5
Total North America	**18,670**	**27,542**	
India	7845	9645	9.8
China	5910	12,210	8.6
Taiwan	281	358	14
Total Asia	**14,194**	**22,488**	
Brazil	247	341	1.9
Mexico	87	87	0.8
Total Latin America	**533**	**629**	
Japan	1538	1880	12.1
Australia	824	1306	42.7
New Zealand	322	326	80.5
Total Pacific region	**2733**	**3443**	
Egypt	310	365	4.7
Morocco	124	134	4.2
Iran	67	85	1.3
Total Middle East/Africa	**448**	**467**	
World total	**93,835**	**120,798**	

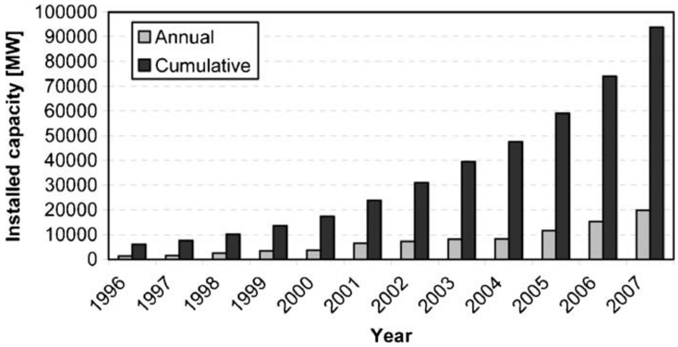


Fig. 4. Global installed wind power capacity [4].

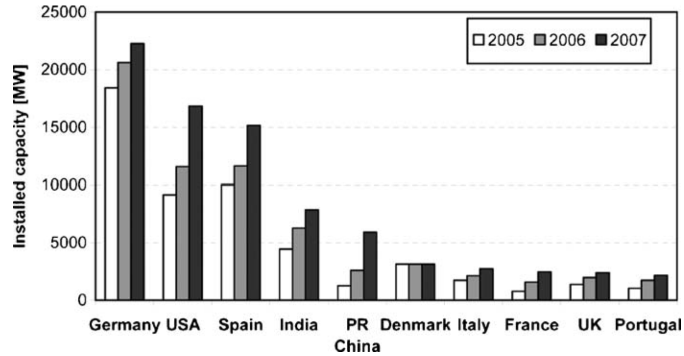


Fig. 5. Top ten countries in terms of total installed wind power capacity in the world [4].

Germany has the highest installed wind capacity with 22,247 MW which is equal the 45% of European and 31.2% of world installed capacity. The top ten wind energy markets are shown in Fig. 5 between 2005 and 2007 [3–5,21,22].

As it is seen from Fig. 5 Germany shows the highest development in installed wind energy capacity with 26% between 2005 and 2007. Spain, USA and India have also high development with 28.4, 26.2 and 20.4%, respectively [4]. The average increasing rate of installed wind capacity in this term for Germany, USA, Spain and India is 36.2, 32.1, 31.1, 25.7%, respectively. The growing rate of Denmark in this term is 6.8%. According to the German Wind Energy Association, in a typical wind year, 8% of Germany's energy requirement can be supplied from the wind farms, and 48,000 people employed by wind energy industry in Germany. Spain, USA and Denmark supply 4, 5, 1 and 20% of their electrical energy from wind, respectively. The highest wind energy rate in total electrical energy belongs to the Denmark [5]. Fig. 6 shows installed wind power capacity by region.

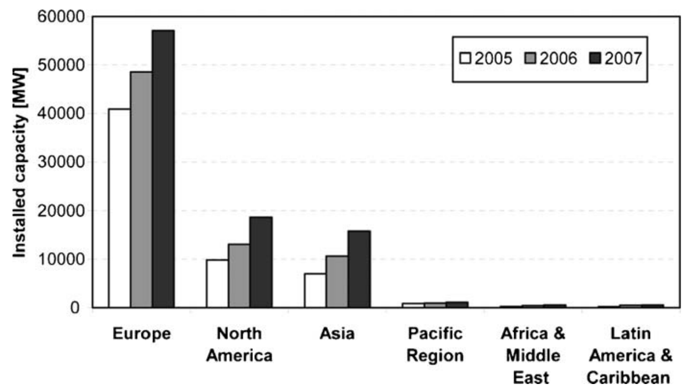


Fig. 6. Installed wind power capacity by region [4].

Table 2
Moderate scenario for future global wind energy development [4].

	Cumulative (MW)	Growth rate (%)	Annual included power (MW)
2005	59,078	21	11,524
2006	71,344	19	12,266
2007	84,837	18	13,493
2008	99,862	17	15,025
2009	116,637	17	16,774
2010	136,543	16	19,905
2015	279,682	15	37,972
2020	560,445	13	77,365
2025	897,014	6	75,507
2030	1,128,707	3	58,260
2035	1,285,087	2	65,057
2040	1,399,133	1	97,737
2045	1,487,253	1	91,476
2050	1,556,901	0	70,957

Since wind power has significant development in electrical energy production in the European countries and closer Turkey as geographically [24], it is important to determine the installed wind power capacity per km^2 (kW/km^2), and per capita (W/capita) of some European countries (Table 3). Also technical potential of wind energy, installed wind power capacity and the ratio installed

Table 3
Wind energy projections in European Union End 2008 [13].

Country	Technical potential (MW)	Installed wind power (MW)	Installed wind power/ technical potential (%)	kW/km^2	W/capita
Austria	2000	995	42.95	9.77	100.25
Belgium	2000	312	8.87	5.14	16.30
Denmark	14,000	3180	24.34	72.58	582.60
Finland	4000	96	2.95	0.24	15.84
France	42,000	3404	2.20	1.39	12.71
Germany	12,000	23,903	156.6	51.61	222.44
Greece	22,000	985	2.81	4.34	53.96
Ireland	22,000	1002	2.75	7.06	130.42
Italy	35,000	3736	5.22	5.70	22.78
Netherlands	3000	2225	42.63	29.36	76.12
Norway	38,000	428	0.98	0.83	60.54
Portugal	7000	2862	15.6	11.07	101.75
Spain	43,000	16,754	25.32	19.86	250.64
Sweden	20,000	1021	2.95	1.13	57.56
Switzerland	1000	45	1.66	0.28	1.68
Turkey	83,000	433	0.06	0.03	0.67
UK	57,000	3241	2.77	5.57	22.86

Table 4
Installed power capacity by resources in Turkey (MW) [30].

Resources	2003	2004	2005	2006
Fuel-oil + diesel	2222	2222	2222	2122
Imported coal	145	1355	1355	1380
Hard coal	555	555	555	555
Lignite	6763	7813	8173	10,573
Natural gas	12,582	13,352	13,352	13,382
Geothermal	15	15	15	15
Others	291	291	291	510
Total thermal	22,788	25,818	26,178	28,539
Hydraulic	12,721	13,283	14,144	14,894
Wind	19	19	19	84
Total	35,528	39,120	40,341	43,451

Table 5
Estimated data of wind energy usage in Turkey [8].

Years	Electric energy consumption (billion kWh)	Established wind energy power (MW)	Average wind energy production (million kWh)	Its share in total electric energy consumption (%)
2000	134	300	640	0.47
2005	190	1300	3000	1.57
2010	260	2800	5900	2.26
2015	340	4100	10,130	2.97
2020	480	6500	15,580	3.24
2025	570	10,200	20,110	3.52
2030	660	12,500	24,865	3.76

wind power capacity to technical potential are given in Table 3 [13]. As it is seen from Table 3 the ratio of installed wind power to technical potential in Germany reached to 153.56%, the installed wind power capacity is 6427.5 MW higher than the technical potential. This rate in Austria, Netherlands, Spain and Denmark are 40.95, 40.63, 23.32 and 22.34%, respectively. Although Turkey has the highest technical wind energy potential, this rate as given in table is lowest. Germany has the highest installed wind capacity but Denmark has the highest install capacity both per km^2 and per capita [3–5,13].

5. Turkey's electrical energy status

Turkey's total installed power capacity obtained from hydraulic, thermal and wind sources, is 43,451 MW at the end of the 2006 a shown in Table 4. Distribution of the installed power capacity of Turkey according to the sources is given in Fig. 7. As it is seen from Table 4, the rate of thermal sources power plants is very high and approximately half of these are natural gas plants. According to the estimation of Energy and Natural Sources Ministry, installed power would be necessary 60 GW until 2010 and 105 GW in 2020 [24–26].

The total gross electrical energy production in 2006 was 168,783 GWh and changes in the production rate depended on the economical situations and technological developments. Average increasing rate was approximately 8.82% in this term [27,28]. Although electrical energy production has increased gradually, there was a decrease in electrical energy production in 2001, because of industrial electrical energy demand decreased as a result of economical crisis throughout the country [13]. However, the natural gas share of the world in production electrical energy is 19.3% [2]. Since Turkey imports almost all required natural gas, this high rate usage in producing electricity than the world is an important point to be examined economically [27]. On the other hand, the share of lignite in electricity generation increases from 20% in 2003 to 30% in 2006 [27]. While electrical energy production from the wind has grown rapidly, in the World, especially in the Europe, usage of wind sources in Turkey is very low.

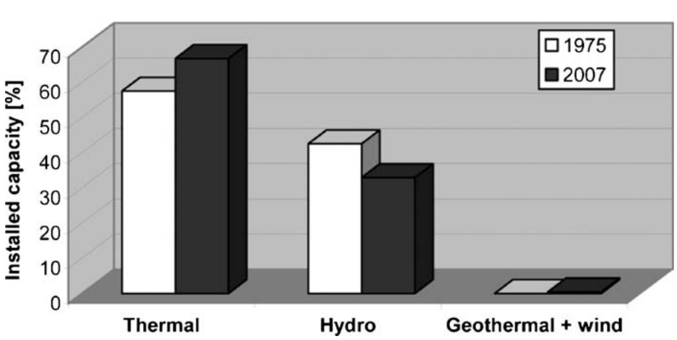


Fig. 7. Shares of installed capacity of Turkey's electric power plants [11].

6. Wind energy in Turkey

Turkey is located between 268 and 458 east latitudes to the Greenwich, and between 368 and 428 north longitudes to the Equator. Most of the land of Turkey is in Asia and the small part is in Europe. Turkey surrounded by sea on its three borders (Aegean Sea on the west, Black Sea on the north, Mediterranean on the south and Marmara as an inner sea). Aegean, Marmara and East Mediterranean coasts have high wind potential. According to the "Turkey Wind Map", prepared by General Directorate of Electrical Power Resources (EIE), wind speed at 50 m height and outside the residential areas, at Marmara, West Black sea, and East Mediterranean coasts and inner parts of these regions are 6.0–7.0, 4.5–5.0 m/s, respectively. The north-west Aegean coasts are also 7.0–8.5 m/s, and in the inner parts are 6.5–7.0 m/s [28]. In addition to this, meteorological data by the USA space studies have been shown that Turkey has high wind capacity [5,29].

It is estimated that Turkey's technical wind energy potential is 88,000 MW, economical potential is approximately 10,000 MW depending on the technical condition [30]. The EIE's wind atlas reported that, Turkey's technical wind energy potential was 83,000 MW, production potential was 166 TWh/year [28,30]. But, Turkey total installed wind capacity is only 1300 MW in 2005 and will be 2800 MW in 2010 as shown in Table 5 [4,30].

The first wind power plant was installed in 1998 Cesme-Germiyan with 1.74 MW capacity [29]. In 1998, the ARES wind farm was built in Cesme-Alacatı and includes 12,600 kW wind turbines [29,31]. The biggest wind energy power plant in Turkey has 10.2 MW capacity constructed in Bozcaada in 2000 [16,28]. There are also some wind power plants established by private sector to supply their electrical energy needs. These are installed in Izmir in 2003 with 1.5 MW capacity and in Istanbul in 2003 with 1.2 MW capacity [26]. Installed wind power capacity for electrical energy production is shown in Fig. 8. Figs. 9 and 10 also show scattering of wind velocity and potential of 10 m high in Turkey, respectively.

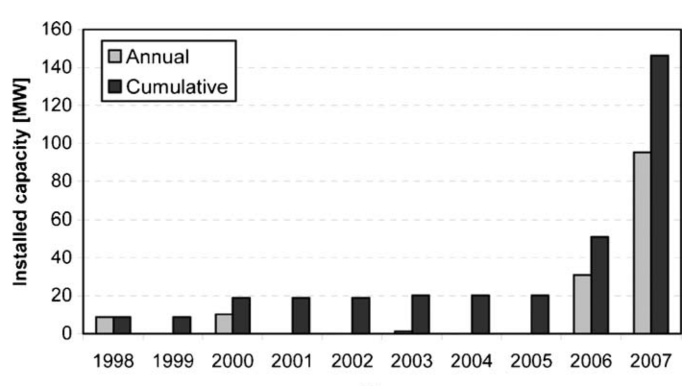


Fig. 8. Installed wind power capacity in Turkey [11].

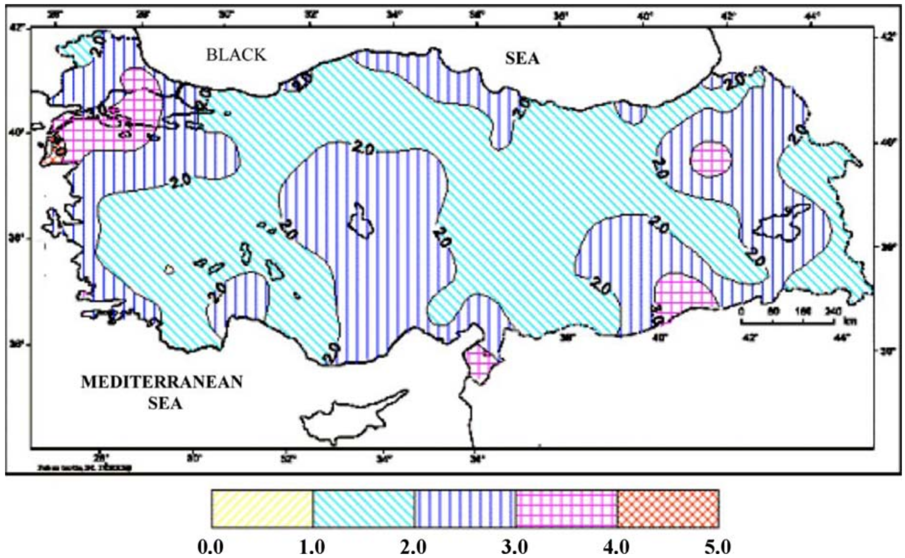


Fig. 9. Scattering of wind velocity of 10 m high [28].

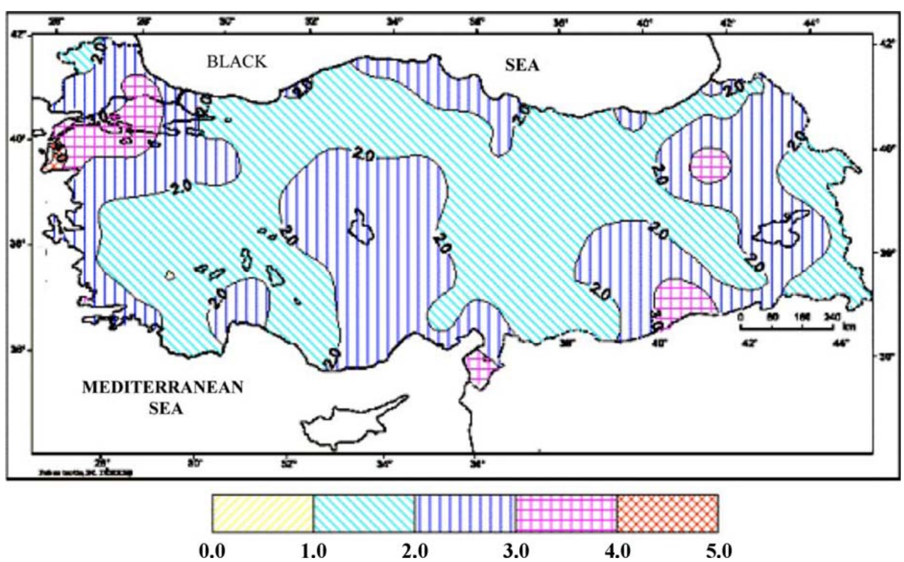


Fig. 10. Scattering of wind potential of 10 m high [28].

In January 2009, 253 projects got licensed from Energy Market Regulatory Authority (EPDK) to produce electricity. Thirty-six of 253 projects are wind power plant projects. The planned capacity of these 36 wind power plants change between 0.76 and 140 MW and total capacity of all plants are 1496.92 MW. These wind projects were distributed in Marmara region (20 projects), Aegean region (14 projects), Mediterranean region (10 projects), and South-East Anatolia region (2 projects), with 661.46, 379.01, 404.45, and 53 MW, respectively. Geographical region, location, installed capacity, estimated gross electrical energy values and capacity factor of these projects are shown also in Table 6. As shown in Table 6, total installed capacity is 1,070,000 MW and it is estimated that totally 4867 GWh electrical energy will be produced which is equal to 3.4% of Turkey 2008 total electrical energy production [26].

At the end of 2009, 120 new wind power plant applications have been made to get generation license with 3564.63 MW up to January 2005, from the EPDK. Distribution of the projects to the regions is: Marmara (35 projects) with 966.3 MW, Aegean (62 projects) with 1864.6 MW, Mediterranean (20 projects) with 574.3 MW, middle Anatolia (2 projects) with 120.4 MW, and south east Anatolia (1 project) with 47 MW [26].

7. Wind energy supports and prices

In all countries, production of electrical energy from renewable resources is supported. In many countries minimum price system is used widely. Electricity utility must purchase this energy, named as green energy, at a minimum price which is defined [24]. Table 7 shows generation, investment and external costs for various power generation technologies.

In Turkey to increase the usage of renewable energy sources renewable energy law has been accepted [31]. The law, regarding the spread of the use of renewable energy resources (including the wind energy) with the aim of producing electrical energy, the economic and quality integration of these resources into the

Table 6
Wind power projects in Turkey [26].

Location	Company	Commissioning date	Installed capacity (MW)	Turbine manufacturer	Number of turbines	Turbine capacity (MW)
Izmir-Ceşme	Alize A.S	1998	1.50	Enercon	3	500
Izmir-Çeşme	Güçbirliği A.S	1998	7.20	Vestaş	12	600
Çanakkale-Bozcaada	Bores A.S	2000	10.20	Enercon	17	600
Istanbul-Hadimköy	Sunjüt A.S	2003	1.20	Enercon	2	600
Balıkesir-Bandırma	Bares A.S	2006	30.00	GE	20	1500
Istanbul-Silivri	Ertürk A.S	2006	0.85	Vestas	1	850
Izmir-Çeşme	Mare A.S	2007	39.20	Enercon	49	800
Manisa-Akhisar	Deniz A.S	2007	10.80	Vestas	6	1800
Çanakkale-Intepe	Anemon A.S	2007	30.40	Enercon	38	800
Çanakkale-Gelibolu	Dogal A.S	2007	14.90	Enercon	18	1700
Hatay-Samandağ	Deniz A.S	2008	30.00	Vestas	15	2000
Manisa-Sayalar	Dogal A.S	2008	30.60	Enercon	38	800
Izmir-Aliağa	Innores A.S	2008	42.50	Nordex	17	2500
Istanbul-Gaziosmanpaşa	Lodos A.S	2008	24.00	Enecon	12	2000
Istanbul-Çatalca	Ertürk A.S	2008	60	Vestas	20	3000
Balıkesir-Samli	Baki A.S	2008	114.00	Vestas	30	3000
Muğla-Datça	Dares A.S	2008	28.80	Enercon	60	800
Hatay-Samandağ	Eze Ltd. Sti	2008	35.10	Nordex	39	900
Hatay-Samandağ	Eze Ltd. Sti	2008	22.50	Nordex	9	2500
Aydın-Didim	Ayen A.S	2008	31.50	Suzlon	15	2100
Izmir-Çeşme	Kore A.S	2008	15.00	Nordex	6	2500
Balıkesir-Susurluk	Alize A.S	2008	19.00	Enercon	23	1700
Osmaniye-Bahçe	Rotor A.S	2009	135.00	GE	54	2500
Izmir-Çeşme	Mazı A.S	2009	22.50	Nordex	9	2500
Balıkesir-Bandırma	Borasco A.S	2009	45.00	Vestas	15	3000
Tekirdağ-Sarköy	Alize A.S	2009	28.80	Enercon	15	2800
Balıkesir-Havran	Alize A.S	2009	16.00	Enercon	8	2000
Çanakkale-Ezine	Alize A.S	2009	20.80	Enercon	11	2800
Hatay-Belen	Belen A.S	2009	30,00	Vestas	10	3000
Total			1,070,00			

Table 7
Generation, investment and external costs for various power generation technologies [5].

Technology	Generation cost (cents/kWh)	Investment cost	All external costs[a] (cents/kWh)
Coal, thermal	3–5	1.0–1.5	2.0–15
Nuclear	3–8	1.2–2.0	0.2–0.6[b]
Gas combined cycle	3–5	0.5–0.7	1.0–4.0
Small hydro	5–10	0.8–1.2	–
Biomass, thermal	4–10	1.5–2.5	–
Wind	3–5	0.8–1.5	0.05–0.25
Solar, PV	20–35	6.0–8.0	0.05–0.25
Solar, thermal	15–30	4.0–6.0	–

[a] Estimated cost to society and environment.
[b] Not including nuclear waste and decommissioning cost.

economy, the increase of the resource variety, the decrease of the emission of greenhouse gases, the reuse of waste, the preservation of the environment, and the development of the manufacturing sector needed for realizing these goals, was enacted on 18 May 2005, with the official number of 5346 [13,32].

The electrical energy produced from the renewable energy resources stated in this law was officially guaranteed to be purchased. The price that applies to the purchase in a given year until 2011 is the average wholesale price of the previous year determined by the EPDK. The board of ministries is entitled to increase this price by at most 20% [32]. The average electricity price of Turkey is 8.56 YKr/kWh for the year 2007. It is stated by the World Wind Energy Association (WWEA), the price determined as the purchase guarantee for wind energy in the renewable energy law should be raised to the level in the European Wind Markets [13]. In addition to the purchase guarantee, in the case of the use of the public lands and forests for the production of electrical energy from the renewable resources, these lands can be rented or awarded access by the Ministry of Environment and Forestry and/or Finance.

8. Conclusions

Wind energy is arguably the cleanest electricity generation technology, but, like any other industry, does have environmental impacts. The wind industry takes its responsibility to reduce the impacts of wind energy on the environment very seriously, and, since the early days of this relatively young industry, significant improvements have been made with regards to the sitting of wind farms and the design of turbines.

Although estimated installed wind power capacity and average electrical energy production from the wind in eighth 5-year improvement plan for the year 2008 are 753 MW, 1986 GWh, respectively, the realization values are 433 MW, 996 GWh. The installed wind capacity of Turkey is only 0.22% of Turkey's total economical wind potential. However this rate will be increased to 14.27% after installing the licensed projects.

It is possible to improve the present wind energy capacity to the European countries' levels by increasing government supports, constituting necessary technological background to connect to the interconnected network. Turkey should invest to the wind turbine technology both for using its wind potential more cheaply in a long period and for supplying job opportunity to the people. Turkey will become technologically independent and could export technology. Conclusively, the use of present wind potential is very important from both economical and environmental respects.

When considering the energy reserves in the world, it is obvious that wind power is very important. The depletion of the world energy reserve is 200 years for coal, 65 years for natural gas, 40 years for petroleum and infinite for wind. Since the energy reserves are going to end in the future, for Turkey who imports most of its fossil energy sources will most probably be a great problem. Therefore, it is necessary to use existing hydraulic sources accompanying with wind energy which is renewable sources, to obtain electrical energy.

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